

## **Improving production systems with lean: a case study in a medium-sized manufacturer**

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**Abstract:** Lean principles and tools have been increasingly employed in companies across several sectors, with numerous successful implementations both inside and outside production environments. In the case of Portuguese companies, few works have reported the application and corresponding results of lean, and even fewer focusing on small and medium sized companies. This work presents a case study of an implementation of several lean principles and tools in the production sector of a Portuguese medium-sized screw cap manufacturer. Visual management, A3 thinking, and single-minute exchange of die (SMED) were employed to identify and reduce inefficiencies and waste in the shop floor. The implementation of these principles and tools is detailed, showcasing the necessary adjustments for being correctly embedded in the company's culture. Qualitative and quantitative results are presented concerning the case study, where a continuous improvement culture was adhered to and a significant gain in productivity could be observed.

**Keywords:** lean tools; case study; bottle cap industry.

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## **1 Introduction**

In Portugal, large-sized companies are only a tiny portion of industry-specific organisations. According to the Portuguese National Statistics Institute in 2013, the proportion of micro, small and medium sized enterprises (SME) was respectively 96.2, 3.2 and 0.5; their business volume 17.2%, 17.6% and 19% of the national total. Many of these small/medium-sized companies still lack good management practices and philosophies. In larger companies lean thinking has shown to be able to provide a set of good practices from both efficiency as well as organisational culture point of view.

Lean aims in reducing wastes in order to become highly responsive to customer demand, while efficiently delivering quality products (Womack et al., 1990). Originated in Toyota, impressive gains have been reported in several other companies, even when applied outside production environments (Womack et al., 1990; George, 2003). Although scarcely reported, lean may also prove beneficial in smaller companies. However, lean is not without its drawbacks, the most commonly mentioned is the impact it has on employees and their working conditions, leading to increased stress and reduced work content (Eklund et al., 2015; Langstrand and Drotz, 2016).

Lean in production systems has been recently reviewed by Marodin and Saurin (2013), where the majority of works in the literature are from unspecified manufacturing, service, automotive and electronics components sectors; half concerning companies from the USA or the UK. Only two works were identified as specifically addressing SMEs, both regarding companies located in India: Panizzolo et al. (2012) and Vinodh and Joy (2012). These works report the performance benefits resulting from adopting lean manufacturing in several SMEs (four in the former and 60 in the latter), not detailing however how it was implemented and main challenges faced.

Implementing lean practices in production systems is not trivial and often fails to meet objectives and expectations. A general view of critical success factors for lean implementation in manufacturing SMEs can be found in Achanga et al. (2006) where ten UK companies are analysed. Overall, factors can be grouped into (Marodin and Saurin, 2013; Achanga et al., 2006): human; work organisation; technical; and external environment. From these components of a socio-technical system, the most commonly identified factors are within work organisation, namely the importance of management support and/or commitment. This is in line with the view by Bhasin and Burcher (2006) which points to managerial and cultural issues as the most relevant factors. This encourages further investigating and analysing lean implementations in different cultural environments and management practices, possibly leading to the development of new methods/tools within the lean ecosystem.

Successfully introducing new management practices requires understanding the context where they are effective and the organisation where they are to be implemented (Sousa and Voss, 2008). In the case of lean, many obstacles may appear if not planned properly, namely (Hodge et al., 2011): resistance to change; shop floor employees reluctant to make suggestions for improvement; disconnect among companies' departments; and lack of motivation and incorrect mindset. These obstacles and the need for the lean philosophy to be interiorised by everyone in the company make it not only difficult to put into practice but even harder to make it successful and sustainable (Maia et al., 2017). Moreover, lean initiatives have had narrower scopes which, together with variation in operationalisation, makes difficult to predict and correctly measure the outcomes of these initiatives (Langstrand and Drotz, 2016).

In Portugal, as with the rest of the world, lean has been mostly adopted in large companies, often part of international groups. Two recent works addressing lean practices and tools in several industrial sectors in Portugal are by Silva et al. (2010) and Alves et al. (2011).

Silva et al. (2010) compare lean practices among Portuguese, Italian, the UK and US companies based on surveys, and conclude that Portuguese companies present a lower level of lean practices. Moreover, lack of support from top management was seen as the major barrier, possibly the reason why Portugal is considered well behind the other analysed countries. The authors also stress the need to disseminate lean principles to practitioners, mostly in SMEs.

In Alves et al. (2011), 41 lean projects, taken place from 2001 to 2010, are analysed. Out of the 18 companies involved, half are international companies located in Portugal, and seven can be considered SMEs (most of them national). The biggest incidence of lean projects is in the larger international companies, suppliers to the automotive industry, and an increasing interest in lean is hinted based on the data of the last years of the study. The lack of quantification of results is highlighted by the authors, which consider it to be the major reason for the unwillingness of managers to adopt lean. Unclear or not easily measurable benefits may have discouraged managers, which mostly rely on economic reasoning and judgement.

Therefore, the main purpose of this work is to further extend the understanding of lean principles and tools by analysing and quantifying its impact in the context of Portuguese SMEs. To that extent, this paper details a case study on the first steps of the lean journey of a Portuguese screw cap manufacturing company, characterised by low variability – high volume orders. Seen as not easily applicable to industries with large batch processes, this work presents and discusses implementation aspects of several employed lean tools, techniques and principles, namely, visual management, 5S, A3 thinking and single-minute exchange of die (SMED). The resulting main outcomes are put forward and financially quantified, in order to help practitioners of Portuguese companies with similar characteristics and/or organisational culture in their own lean journeys.

The remainder of the paper is structured as follow. Section 2 introduces the theoretical concepts and contextualises the used principles and tools. In Section 3, the research design for the case study is described. Section 4 contextualises the case study and then presents and discusses the main results obtained. Conclusions and future research directions are drawn in Section 5.

## **2 Literature review**

Lean, lean manufacturing, or lean thinking, can be defined as a philosophy which relies on a set of practices and tools in order to minimise waste for improving organisational performance (Womack et al., 1990). Practices commonly used in lean companies are, among others, value stream mapping (VSM), visual management, 5S, just-in-time, and kanban. The wastes to be reduced can form the acronym DOWNTIME (Liker, 2004):

- Defects – rework, scrap, incorrect information.
- Overproduction – producing more than required or before it is required.
- Waiting – time wasted waiting for parts, information, instructions, equipment or for the next step in a process.
- Non-utilised talent – underutilisation of people's talents, skills and knowledge.
- Transportation – unnecessary moving of people, products and information.
- Inventory – excess parts, products, materials and documentation.
- Motion – unnecessary movements being performed by people.
- Extra-processing – more work or higher quality than needed.

Lean journeys typically start out by defining value (Khan et al., 2015). This is usually done with an initial VSM, raising awareness on the advantages of lean and starting to change mentalities (Marodin and Saurin, 2013). 5S methodology is often employed afterwards, in order to organise production environments and facilitate the identification of problems. Following a continuous improvement culture major causes of wastes are identified afterwards, which are to be addressed using the most appropriate tools (Pearce and Pons, 2013). The existence of this continuous improvement culture in the daily activities of employees is what is often considered the key success factor of lean (Dombrowski and Mielke, 2013). In SMEs, people related factors, management, and lack of key knowledge and know-how have shown to be major lean barriers (Zhou, 2016).

More recently, lean has been complemented with other methodologies in order to further increase its efficiency. These are the cases for: lean six sigma, where variation minimisation in quality is also sought (Drohomeretski et al., 2014); and systems thinking approaches, such as theoretic accident model and processes (STAMP), which enables to acquire more information concerning a system under analysis and take into account safety concerns (Sousa et al., 2017).

In the case study detailed in this work, lean was starting to be introduced in the company. Workspaces were generally poorly organised and with excess raw materials and end product, making a priority the use of the 5S methodology. Then, main waste-causing issues were identified and analysed with A3 thinking. One of the main issues was changeover times, prompting the application of SMED. As these tools were employed or the main drivers of the first lean steps of the case study herein, they will be presented and contextualised as follows, namely visual management, 5S, A3 thinking, and SMED.

## 2.1 *Visual management and 5S*

Visual management, in a broad perspective, aims to improve performance by aligning organisational vision, values, goals and culture with other management systems, processes and stakeholders by means of stimuli (Liff and Posey, 2004). These stimuli are used to communicate information, making it available and easily interpretable.

In the context of production environments, visual control aims to bring visual management to workplaces (Ortiz and Park, 2011). By employing visual techniques and communicating typically through visual cues or auditory stimuli, the goal is to obtain visual workplaces. A visual workplace is a work environment that is self-ordering, self-explaining, self-regulating and self-improving, where visual solutions are employed for ensuring everything happens as is supposed to (Galsworth, 1997).

Ultimately, visual management will allow that anyone can easily know what is right and wrong by simply making a tour of the work environment; greatly facilitating managing it (Schonberger, 1986). Successful implementations have reported gains in production throughput ranging 15%–30% (Galsworth, 1997).

The following steps may be followed for implementing visual management:

- Organisation of the workplace using the 5S methodology.
- Development of a visual communication system ensuring the right information is provided in the right format.
- Creating visual measures for collecting relevant data for decision-making and providing feedback on work output and quality.
- Control all aspects of the workplace creating an error-proof environment.

A critical component of visual management is therefore the 5S methodology, allowing preparing work environments for reaching the goal of a visual workplace (Hirano, 1996).

5S is a workspace organisation method whose name derives from the first letter of five Japanese words: seiri, seiton, seiso, seiketsu, and shitsuke. Corresponding to the methodology's steps, it has been translated to sort, set in order, shine, standardise, and sustain. Two different although complementary visions are inherent to 5S (Jaca et al., 2014): a more conceptual by Osada (1991), viewing it as a strategy for organisational improvement towards improving efficiency and working conditions; and a more practical by Hirano (1996), portraying it as a tool for eliminating waste.

The first vision is more in line with the Japanese culture; making applications in that country mostly focused on a broader perspective of the methodology, being a core management approach (Gapp et al., 2008). The vision by Hirano (1996) has been mostly applied in western organisations, where companies focus mainly on the first steps, possibly underestimating the benefits of the method (Ho, 1998; Gapp et al., 2008). As follows, the focus will be on Hirano's view, although not disregarding the holistic conception of the methodology.

Aiming maintaining workplaces in good conditions (through storage, organisation and cleanliness) 5S is a tool that encourages continuous improvement; contributing with little effort and cost to the cost-effectiveness of organisations (Bayo-Moriones et al., 2010).

The steps of the methodology can be briefly summarised to:

- *Seiri* (sort) – consists in identifying and classifying all objects that are in the workplace, keeping only the ones necessary for the workspace' processes.
- *Seiton* (set in order) – items being kept in the workplace are to be organised and stored in suitable places.
- *Seiso* (shine) – workplaces are to be cleaned regularly and all tools and equipment must always be in normal operating conditions.
- *Seiketsu* (standardise) – aims ensuring that organisation, storage and cleaning rules are standardised and followed.
- *Shitsuke* (sustain) – maintain cleanliness and items stored in their designated places, perform regular inspections and keep equipment in good conditions.

Although easy to grasp, its successful implementation highly depends on the acceptance, involvement and commitment of both employees and top management (Dennis, 2007). If correctly implemented, it may bring several advantages to organisations, namely (Kumar et al., 2006; Gapp et al., 2008): efficient, organised and clean workplaces; better working conditions; increased productivity, quality, safety and motivation of employees; reduction of costs, unproductive time, space and movements; better organisational values; and a better view of the problems.

## 2.2 A3 thinking

A3 thinking is a structured problem-solving approach built around the plan-do-check-act (PDCA) cycle which is both a way of thinking and a tool. Developed by Toyota, its name is based on the size of the paper that has traditionally been used, which corresponds to the A3 of the A series paper sizes (Sobek and Smalley, 2008).

The PDCA cycle is a well-known continuous improvement process which follows the scientific method (Moen and Norman, 2010). Giving name to the procedure, it is separated into the steps: plan, where the problem is studied and planning occurs; do, where the plan is implemented; check, where effects of implementation are measured and analysed; and act, where, if successful, actions are taken to implement the new state as standard, correct it otherwise. The PDCA cycle approach is also used for other problem-solving approaches in lean, such as kaizen events, where the focus is smaller, shorter-term improvements (Kanaganayagam et al., 2015).

According to Sobek and Smalley (2008), A3 thinking intrinsically enables the implementation of PDCA, focusing on collaborative problem solving and demanding objectivity, coherence, and synthesised and distilled information. Moreover, it provides an organisationally-aligned systems approach emphasising processes and results. The though process is vital to the use of the tool: the A3 report.

Although some variations may occur, the A3 problem-solving report typically includes the following elements inside boxes and in a single page (Shook, 2008; Sobek and Smalley, 2008):

- Theme – indicating the problem being addressed.
- Background – detailing relevant background information and context for fully understanding the importance of the problem.

- Current condition – describing the current state of the system that produced the problem, possibly using diagrams.
- Goal statement – where the desired outcome is identified.
- Root-cause analysis – establishes causality of most likely direct root cause(s) based on the situation analysis; the ‘5 why’s’ method is commonly used.
- Countermeasures – proposes countermeasures for addressing the root cause(s), often using diagrams of how the system will work (target condition).
- Implementation plan – outlining the steps for reaching the target condition, listing what must be done, when it needs to be done, and the responsible person.
- Follow-up actions – mapping the follow-up process, indicating how and when improvement of the system will be measured.

These reports should use visual representations and are not an end state but a way to communicate and guide improvement of relevant problems or projects.

### 2.3 *Single-minute exchange of die*

SMED is a methodology for the systematic reduction of equipment changeover times. Developed by Shingo (1985), and often used in the context of lean, the goal is to reach times of less than ten minutes (i.e., single-digit minutes) between the end and beginning of two different production runs.

As opposed to traditional mass manufacturing, and in line with lean principles, today’s production systems focus on higher flexibility (McIntosh et al., 2007). This requires that changeovers occur more frequently, making the reduction of corresponding times vital; moreover as most of the activities done in changeover are non-value adding, and therefore target for elimination. This makes SMED not only an effective cost-reduction tool but also a way to help organisations become more efficient and competitive (Mika, 2006).

Typically, changeover is composed of three main periods (Mika, 2006; Henry, 2012): run-down, where material from the previous production run is removed; setup, where machines are converted to fit the following production; and run-up, where initial production adjustment and quality checking occurs to ensure the return to a steady-state production.

Although most emphasis was originally placed in the setup period, the remaining periods are equally important, and SMED has been extended to also address them (Ferradás and Saloniitis, 2013). Additionally, several leveraging tools have been put forward to complement the original proposal (McIntosh et al., 2007).

As originally proposed by Shingo (1985), the three main SMED stages are:

- Separate – where activities are classified as external or internal, i.e., if they can be performed while the machine is working or not.
- Convert – using organisational or equipment design changes there is an attempt to convert internal activities into external.
- Streamline – changeover operations must be streamlined and simplified by reduction and elimination; internal activities should be prioritised.

Successful implementations have also highlighted other important aspects that should be taken into account, namely (Lopes et al., 2015; Ferradás and Salonitis, 2013): the choice of the correct team; defining measurable and achievable objectives; attention to the specificities of the machines, company and sector; and employee engagement and empowerment.

### **3 Research methodology**

The case study method is used to investigate the impact of lean principles and tools in the context of a Portuguese SME. Case study research aims to explore and understand complex phenomena. Preferred when examining real world events, it has consistently been one of the most powerful research methods in operations management (Voss et al., 2002). Moreover, many of the concepts and theories in this field, including lean approaches, have been developed through field case research (Voss et al., 2002).

This research was composed of the following phases: literature review; data collection; identification of processes being addressed; understanding existing and new processes; and analysis and interpretation of results.

The literature review focused in general lean principles and tools and its applicability in Portuguese SMEs, namely in production environments. Data collection was done throughout the period under analysis using primary and secondary sources. Primary data was obtained mostly through observation and collection of quantitative data regarding the production area. Secondary data was collected from historical records in the companies' databases. Identification of processes to be addressed, its understanding, proposed changes and subsequent analysis are detailed in the following section.

The case study reported hereafter concerns a Portuguese company which produces capsules for the wine industry and will be named Alpha for confidentiality reasons. Alpha is a medium-sized company with around 90 employees and a sales volume of 13 million Euros in 2014. It is an 84 year-old family business which in 2009 moved to a new facility with a total area of 50,000 m<sup>2</sup>, from which 15,000 m<sup>2</sup> are covered areas. The company exports 70% of its production, which is composed of several types of capsules, namely: PVC, poly laminate, aluminium, tin, hoods, and screw caps.

### **4 Case study in a production system**

The case study addressed in this work took place in 2015 in the screw cap production sector, which will be the focus henceforth. The flowchart of the production process of the companies' screw cap can be seen in Figure 1. Main processes can be grouped into: cutting and stretching, processes 1–4 with two production lines; side printing, processes 5–6 with three production lines; and knurling and cutting, processes 7–10 with two production lines.

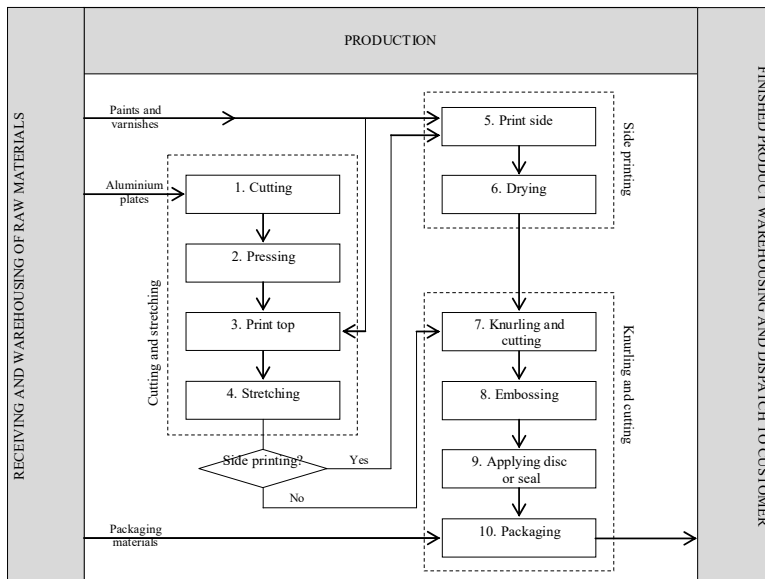
Production starts by cutting aluminium plates into smaller sizes, which are then transported to the pressing machine. In the pressing machine 55 copolas (name given to capsules in initial stages) are obtained for each plate – this is the process generating the largest amount of scrap. The third process is not always required and consists of printing a drawing or picture in the top of the copola. This requires fine-tuning the colours and



ensuring the printing is centred in the top of the copola. Stretching is performed afterwards, where the capsule acquires its final shape: 30 mm diameter × 60 mm height. At the end of this process, capsules are put into containers; once the container has 8,000 capsules it is transported to the next stage.

Side printing (processes 5 and 6) of a drawing or picture is not required for all capsules, and the required processes are done almost simultaneously. Quality check occurs when the side print is drying. Tuning colours and varnishes is often required to be performed several times until quality standards are met.

**Figure 1** Flowchart of the production process of screw caps in alpha

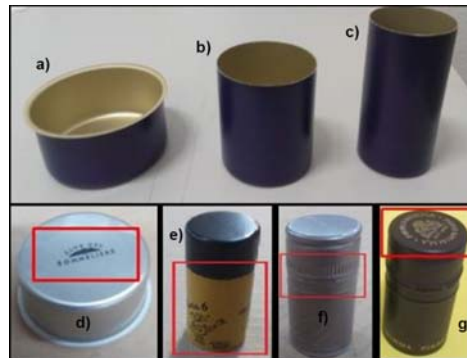


The final stages of the production process consist of knurling and cutting, embossing, applying disc or seal, and packaging. Processes 7 to 9 are usually done in the same machine where: the opening of the capsule is done, allowing it to be applied in bottles later on; and the disc or seal is applied, which ensures the liquid inside bottles does not spill or is in contact with outside environment. Embossing is not always required, depending on clients' specifications, and the most used types of discs are Tin-saran and Saranex. Finally, screw caps are stored in cardboard boxes, storing up to 1,200 caps each. These are stacked in pallets and sent for warehousing and later dispatched to customers. The several stages of the screw cap in the production process can be seen in Figure 2.

Several wastes in the production process were acknowledged; most visible ones were overproduction, defects, and frequent unscheduled machine stoppages. Intending to reduce wastes and batch sizes, and instil a continuous improvement culture, Alpha felt the need to adopt lean. Visual management was to be implemented, starting with 5S.

Afterwards, A3 thinking would be used for helping to identify and solve main issues, among which emerged changeover times, prompting the use of SMED.

**Figure 2** Production stages of the screw cap, (a) copola (b) first stretching (c) capsule or final stretching (d) top printing (e) side printing (f) knurling and cutting (g) embossing (see online version for colours)



#### 4.1 Implementation of visual management and 5S

Following the steps as presented in the literature review, 5S was firstly employed for organising the shop floor. Although having moved recently to the current facilities, the screw caps' manufacturing sector showed general disorganisation: no clear marking for the different sections of the shop floor; excess raw materials in workstations; messy workstations with too much documents; non-conforming product mixed with finished product; excess and unaccounted production; and unused equipment occupying space in the shop floor. Some examples can be seen in the left side of Figure 3.

Firstly, each section and workplace was thoroughly analysed. It was evaluated equipment positioning and organisation, and which tools and documents were required for performing most common operations. With continuous employee's involvement, a list was produced containing all equipment or material to be removed from the shop floor or workstations.

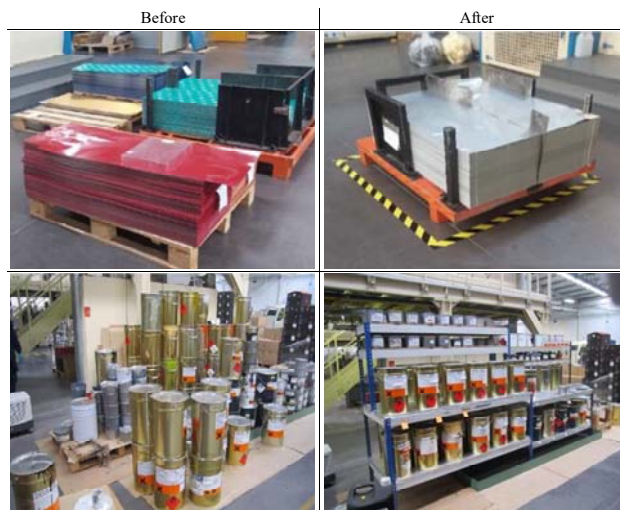
Once the list was finalised and validated, steps were taken to remove items within. Additionally, the sector was reorganised, where most noticeable changes were:

- All areas in the shop floor were defined and outlined accordingly.
- Excess raw material was moved to the corresponding warehouse.
- Organisation and cleaning of several workplaces.
- Non-conforming or inspection-pending products were all placed in a single newly assigned location.
- Excess production was accounted for, labelled, and moved to the warehouse.

- Scattered aluminium plates were placed in the workstations of process 1, which allowed removing some shelves.
- Currently unused machinery was moved away from the production sector and scheduled to be removed.

Along with the organisation and marking of several areas and workplaces, cleaning of the sector also occurred. Scattered metal scrap, shards and filings were placed in containers newly positioned near production lines. The same was done for empty paint and varnish cans and other residues which started having dedicated collection locations (ensuring material separation). These containers were emptied every day by a newly assigned responsible employee.

**Figure 3** Some areas of the production sector before and after visual management and 5S implementation (see online version for colours)



To ensure organisation and cleanliness is maintained, each operator has now approximately 10 minutes per day for cleaning his workplace and place all equipment in its assigned location. Additionally, a more thorough cleaning is now being done on a weekly basis. Information on the new layout and markings was placed on visible locations to help keep standards (emphasising visual representations).

Significant efforts were made in training employees to adhere to the new standards. Given previous bad practices, until current standards are fully embraced, this is to be done continuously. Regular auditing was established, immediately triggering corrective measures whenever issues were found.

This methodology's benefits are not easily measurable; however, it is a critical step for starting to instil a continuous improvement culture. Moreover, it helped to identify problems and further improvements more easily. Concerning space saved in the shop floor, a total of 180 m<sup>2</sup> (around 7.5 %) was saved, allowing the introduction of new

accessibility, such as forklift corridors, which were needed since long. Another clearly identifiable advantage was the reduction of raw-material and work in progress stocks.

Concerning visual management, although an on-going process, several steps were already taken: creating clear identification and marking of areas within production; presenting visual representations of production output and quality data in the shop floor; and creating an error-proof environment by using clearly identifiable colours and representations. Some examples of these changes can be seen on the right-side of Figure 3.

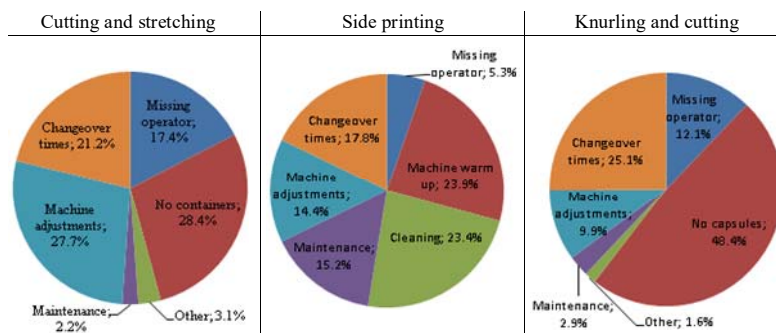
#### 4.2 Using A3 thinking

A3 thinking was introduced into the problem-solving practices of the company. The first major problem identified was unscheduled machine stoppages. Using A3 thinking it was intended to understand the reasons for these stoppages, quantify them to better understand its impact, and attempt to reduce them.

Firstly, some background information was obtained to help contextualise the problem. Machine stoppages have occurred frequently in the past, which could not be attributed to a single cause. A difference in production rates existed between side printing and remaining machines, and several recent changes are also worth noting: working hours per day were increased from 12 to 14 and a new side printing machine was brought in.

The current condition was then analysed and depicted. Data showed that on average stoppages reached 20%, 12% and 19% of scheduled production times (respectively for cutting and stretching, side printing and knurling and cutting machines). These times were further categorised (Figure 4).

**Figure 4** Characterisation of machine stoppages (see online version for colours)



Goal statement was: address main stoppages reasons in order to reduce them.

Root-cause analysis ensued where, for each of the most frequent stoppages types, an in-depth analysis allowed determining most likely root causes.

For cutting and stretching machines, stoppages caused by no containers (28.4%) were due to the significantly different production rates when compared with side printing, leading to an excess of work in progress which would often occupy all containers. Machine adjustments (27.7%) had to be made whenever defects were identified in the

capsules; often requiring to change some parts and subsequent calibration. Typically, most of time spent doing changeovers (21.2%) could be attributed to several inefficient tasks, as large batches were being produced with infrequent changeovers.

In side printing, nearly 50% of stoppages could be attributed to time spent waiting for the machine to reach the ideal temperature in the beginning of the day (23.9%) and in cleaning the machine and its parts at the end of the day (23.4%). Changeovers (18% of stoppages) required cleaning the previously used paint from the machine and tools, changing the tools, and adjust the colours of the paint to be used afterwards.

Concerning knurling and cutting machines, stoppages were mostly due to lack of capsules to continue production, caused by the different production rates between sectors. Changeover times were also significant (25.1%) and concerned changing the discs or seals according to the production order.

Having identified root causes, countermeasures were proposed and implementation plans outlined; these are detailed as follows.

The lack of containers in the first processes meant figuring out the correct number of containers to have in the sector: too much would unnecessarily clutter the workspaces while too little would cause machine stoppages. To provide a reliably estimate on the number of containers, a simulation study was proposed and the necessary steps drawn out. This simulation study has the added advantage of allowing scenario testing of other aspects of the production processes and organisation.

Concerning the machine adjustments due to defects on the capsule (in cutting and stretching), maintenance was scheduled to occur more frequently in order to avoid wear of machine parts.

Changeover times were to be reduced on all three main processes. To that end, SMED was to be implemented; the adopted measures and corresponding results are detailed in Section 4.3.

The main issue in side printing was daily warm up and cleaning of the machine. Actions taken to reduce corresponding stoppages were straightforward: machines were to be turned on 15 min prior to the beginning of the first shift, and cleaning procedures were improved (e.g., reducing unnecessary movement). At this stage, no equipment design changes were considered.

In order to avoid the lack of capsules in knurling and cutting, production rates between processes had to be levelled. Another lean tool, heijunka or production levelling, was scheduled for future implementation. As a short-term measure, the scheduling of production orders should start taking into account the uneven production throughput. Among other measures, products with and without side printing would alternate, enabling to accumulate enough capsules before process 7 and therefore preventing stoppages.

Finally, concerning follow-up actions, on a daily basis the amount and type of stoppages was to be reported. The most commonly reported issues were to be further analysed and attempted solving using dedicated A3 reports and following a continuous improvement philosophy.

### *4.3 Implementation of SMED*

Previous analysis of the production system showed changeovers times as a major cause of machine stoppages. Additionally, the company wanted to reduce the size of batches being produced in order to increase flexibility. To accomplish this, SMED was to be implemented in all machines of the screw cap production sector. Tool change was needed

whenever a new type of product was to begin production, and the change process typically concerned the same tasks. This greatly facilitated the implementation of SMED. Given these were among the first lean steps in the company, organisational based improvements were mainly considered – further equipment design improvements are to be considered in future analyses.

Main implementation stages followed Shingo's original proposal: separate; convert; and streamline. Relevant aspects of the implementation are detailed as follows.

Concerning the separate stage, changeover in cutting and stretching consisted of loading aluminium plates into the machines' elevation platforms. This was performed using forklifts, or by hand whenever there were insufficient dedicated metal pallets – only these pallets would allow loading directly into the machine with forklifts. Total changeover times were on average 252 and 642 seconds, either when using forklifts or by hand. Most of the required tasks were classified as internal, respectively, 82.1% and 93%.

In side printing, between two different production runs, machines must be cleaned and the paint for the next run must be prepared. The machine is divided in two parts (enamelling and offset), each requiring a different procedure. Time required is significant: 2,241 seconds for enamelling, 22% concerning performing internal tasks; and 3,083 seconds for offset with 39% for internal tasks. Knurling and cutting changeover tasks mainly concern swapping the disks inside the machine between Tin-saran and Saranex. Changeover times were on average 835 seconds from which 70% were internal tasks.

Once all changeover tasks were identified and classified, the stage convert ensued.

In the first machines no internal task was able to be converted into external. Loading the plates into the machine and quality check tasks in the run-up period needed the machines to be turned off; in the latter case proceeding otherwise could result in additional non-conform products.

In side printing machines, two types of tasks were converted into external. The first were tasks related with cleaning the machine, for which preparatory steps were now to be taken prior to the machine stoppage. The process was similar to both enamelling and offset, although larger times were required in the latter due to the amount of materials involved. The second type of converted tasks concerned moving materials from the previous and next production runs, which could be done before and after machines started working – with similar times and steps for enamelling and offset.

In knurling and cutting two internal tasks were converted into external: updating the logs of the previous production run, postponed to be performed during the subsequent order; and preparing packaging for the next order, now to be done in advance.

The final stage, streamline, was applied afterwards.

For cutting and stretching loading the plates by hand was considered the biggest reason for extended changeover times. In order to avoid it more dedicated metal pallets had to be obtained. As producing them was a lengthy process, in the meantime usage of available pallets was to be better managed; ensuring there were always enough pallets to load the machines with forklifts.

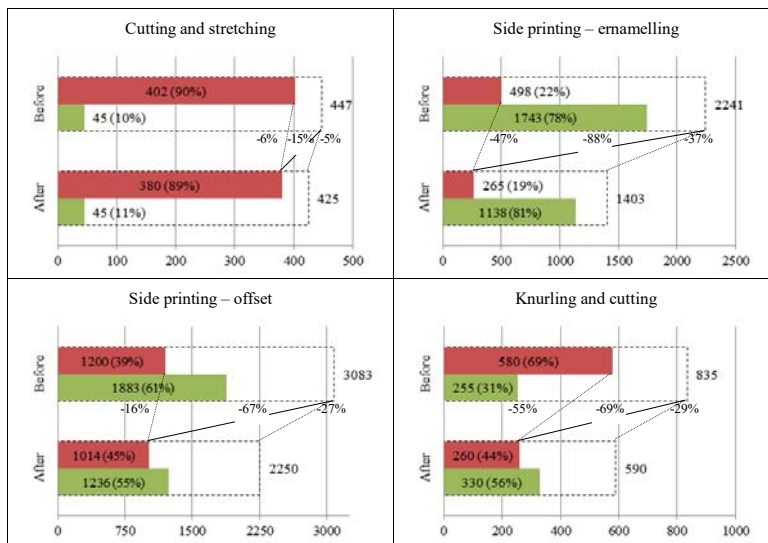
In both enamelling and offset of the side printing machine, specific tasks within machine cleaning and paint preparation were addressed for reduction. For machine cleaning dedicated movable workbenches were created, one for each part of the machine. This allowed fast and easy access to all of the required materials. For paint preparation emphasis was on providing a better organisation and easier reading of the different paints

using visual management; proximity to all the required materials was also ensured with the newly defined layout. Another proposed change was performing tasks in parallel.

In knurling and cutting a new work method was defined for swapping the disks inside the machine. It involved preparing the changeover with the correct amount of disks and changing the way the disks were being loaded into the machine (now using a basin). With the new work method it was possible to eliminate some of the previously performed tasks (e.g., blowing into the machine to clear the used channels). Automation of some of the required tasks was also proposed.

Figure 5 shows the changeover times before and after SMED implementation for the different machines. A clear reduction of these times can be observed, reducing 15% in cutting and stretching, 88% for side printing enamelling, 67% for side printing offset, and 69% for knurling and cutting (the number of workers involved remained the same). With the new changeover operations, visual management was also introduced and employees were generally more engaged in keeping places organised and attempting to improve the process.

**Figure 5** Changeover times for the different machines before and after SMED (see online version for colours)



Note: Internal tasks are in red and external tasks are green; times in seconds.

For ensuring the newly defined procedures were being followed, regular audits were to be performed. As these are among the first lean steps and with employees still starting to grasp and adhere to its main principles, it is important that these operations are reviewed and continuously attempted to be improved (eventually further focusing on equipment design changes).

#### 4.4 Financial analysis

Decision making at industrial level is typically based on economic reasoning, mostly focusing on perceived risk and return on investment (Alves et al., 2011). In the case of the Portuguese industry, the inability to quantify benefits from lean practices may be a major barrier to a more widespread adoption of its principles and tools (Silva et al., 2010). To help tackle this issue, and to further understand the impact of the implemented changes, a financial analysis of the major changes was performed during the study.

Looking at the implemented changes, purchase of the required containers for reducing lack of containers' stoppages was the most impactful. In the simulation study it was estimated that 15 new containers were required. A cost was incurred of 122.45 € for each of the containers, totalling 1,836.75 €. The reduction of this stoppage led to an estimated gain of 1,185 minutes and 770 minutes of production time per month, respectively for the first and second production lines of cutting and stretching. At a production rate of 28,500 caps/h in the first line and 29,700 caps/h in the second line, it amounts to more 944,025 caps being produced, which at an average of 40€ per 1000 caps equals 37,761€ of estimated monthly gain.

Other changes also allowed for gains in production with marginal costs incurred, e.g., reduction in the excess of production, improvement of the changeover times, and redefinition of the areas in the shop floor.

**Table 1** Analysis of the gains in productivity in the different production lines

<i>Production line</i>	<i>Jan–Feb (20 days)</i>	<i>Apr–May (20 days)</i>	<i>Difference</i>	<i>Estimated gain</i>
Cutting and stretching 1	4,129,100 caps	5,016,210 caps	+ 887,110 (+21%)	+ 35,484.40 €
Cutting and stretching 2	4,692,440 caps	6,263,467 caps	+ 1,571,027 (+ 33%)	+ 62,841.08 €
Side printing 1	2,438,100 caps	2,062,125 caps		
Side printing 2	1,755,300 caps	1,353,148 caps		
Side printing 3	2,893,600 caps	3,405,430 caps		
Knurling and cutting 1	4,629,875 caps	4,823,132 caps		
Knurling and cutting 2	4,306,500 caps	5,894,468 caps		

The total gain in productivity can be seen in Table 1. The first column concerns the production line, the second and third columns show the production over a 20 day period before and after major changes were implemented. The two last columns show the difference in productivity and the corresponding estimated gain (assuming an average gain of 40 € per 1,000 caps). Note that the production orders in the two periods were very similar and therefore it does not significantly influence the results. As all capsules have to go through the cutting and stretching processes, these are used to evaluate the total gain in productivity. The overall estimated gain reaches nearly 100,000 € for the 20 day period.

Results extend even past gains in productivity and related key performance metrics. Aspects such as cleanliness of workstations, visual information and empowerment further



instilled in the company's employees a desire to keep on improving, effectively bringing about a cultural change to the organisation.

## **5 Conclusions**

Lean has been achieving significant success in helping companies to eliminate inefficiencies or wastes in the shop floor and in instilling a continuous improvement culture. Lean requires a shift in the organisational culture of the company and several implementation aspects may change significantly from country to country and from company to company, possibly even depending on the sector of activity. In this work a case study of the implementation of lean in a Portuguese SME is presented. Applied in the shop floor of a screw cap manufacturer, the used principles and tools required necessary adjustments to fit the values and culture of the company; employee involvement was considered critical and their engagement a cornerstone to the success of the implementation.

Results show a significant return on investment and a shift in the organisational values and practices. Production flexibility was also improved and problems faced since long were starting to be addressed in a more structured way. These results lead to conclude that lean may also be successfully applied to Portuguese SMEs dealing with low variability–high volume orders. The achieved reduction of waste, increase in productivity, and overall improvement of employee motivation and engagement attest for the potential of lean. This work therefore contributes to the range of successful applications of lean where, often with reduced investment, companies can obtain impactful changes and improvements in their production systems, making it potentially of interest to academics and practitioners.

A limitation of this work is the emphasis on a single case study. As stated by Voss et al. (2002), despite allowing focusing with increase depth on the reported events, it may limit the generalisation of the conclusions drawn. Future work includes following up on the level of lean implementation and cultural change in the company. Additionally, exploring how to incorporate sustainable manufacturing in lean practices is a promising research avenue as well as testing the adopted approaches in companies with similar characteristics.

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